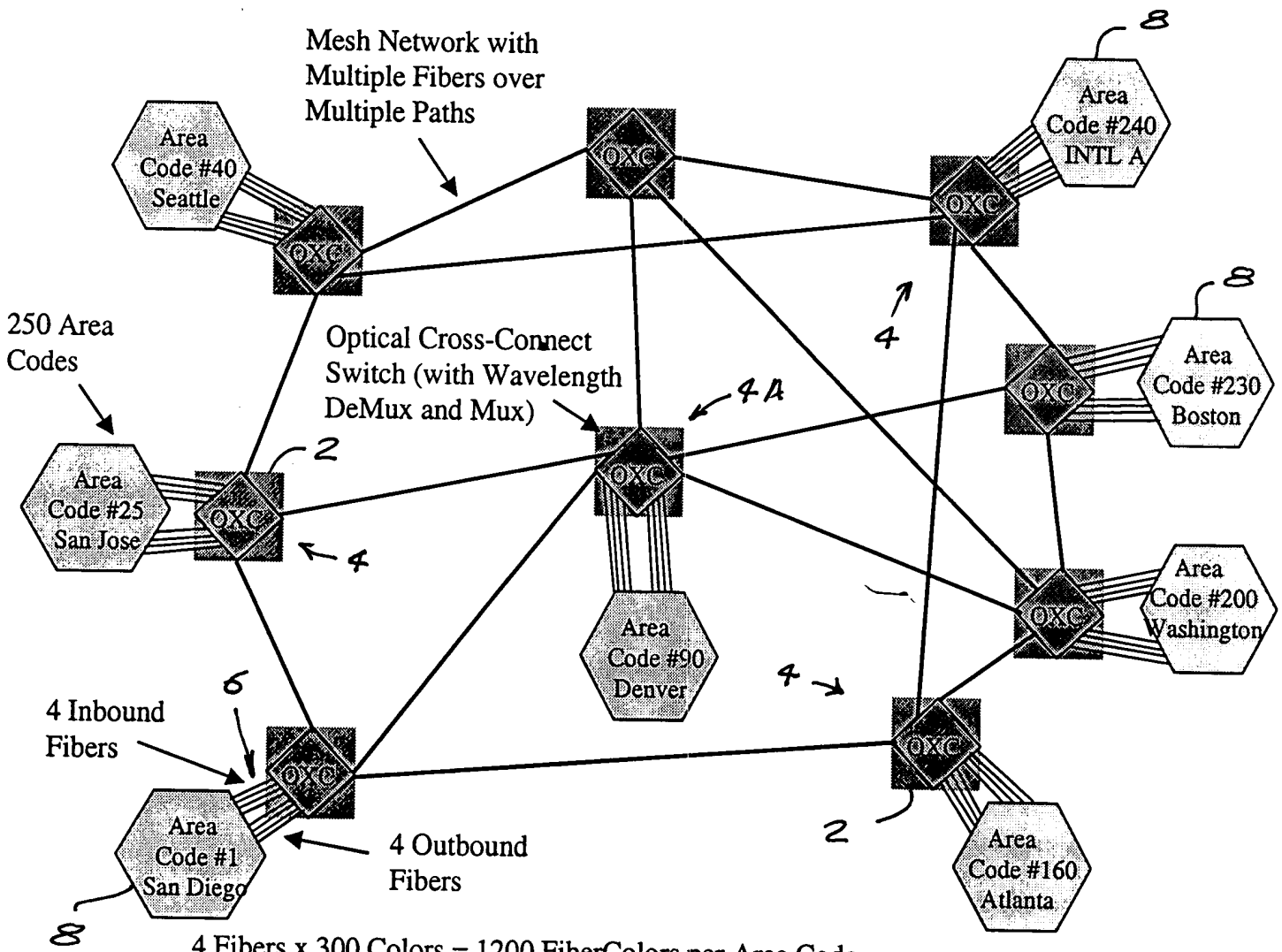

Mesh Network with
Multiple Fibers over
Multiple Paths
Area
Code #40
Seattle
Area
Code #240
INTL A
250 Area
Codes
Optical Cross-Connect
Switch (with Wavelength
DeMux and Mux)
Area
Code #230
Boston
Area
Code #25
San Jose
Area
Code #90
Denver
Area
Code #200
Washington
4 Inbound
Fibers
Area
Code #1
San Diego
4 Outbound
Fibers
Area
Code #160
Atlanta
OXC
8
4
2
6
4 Fibers x 300 Colors = 1200 FiberColors per Area Code
1200 FiberColors x 8.33 GHz /400,000 User Nodes = 25 MHz per User

FIG. 1

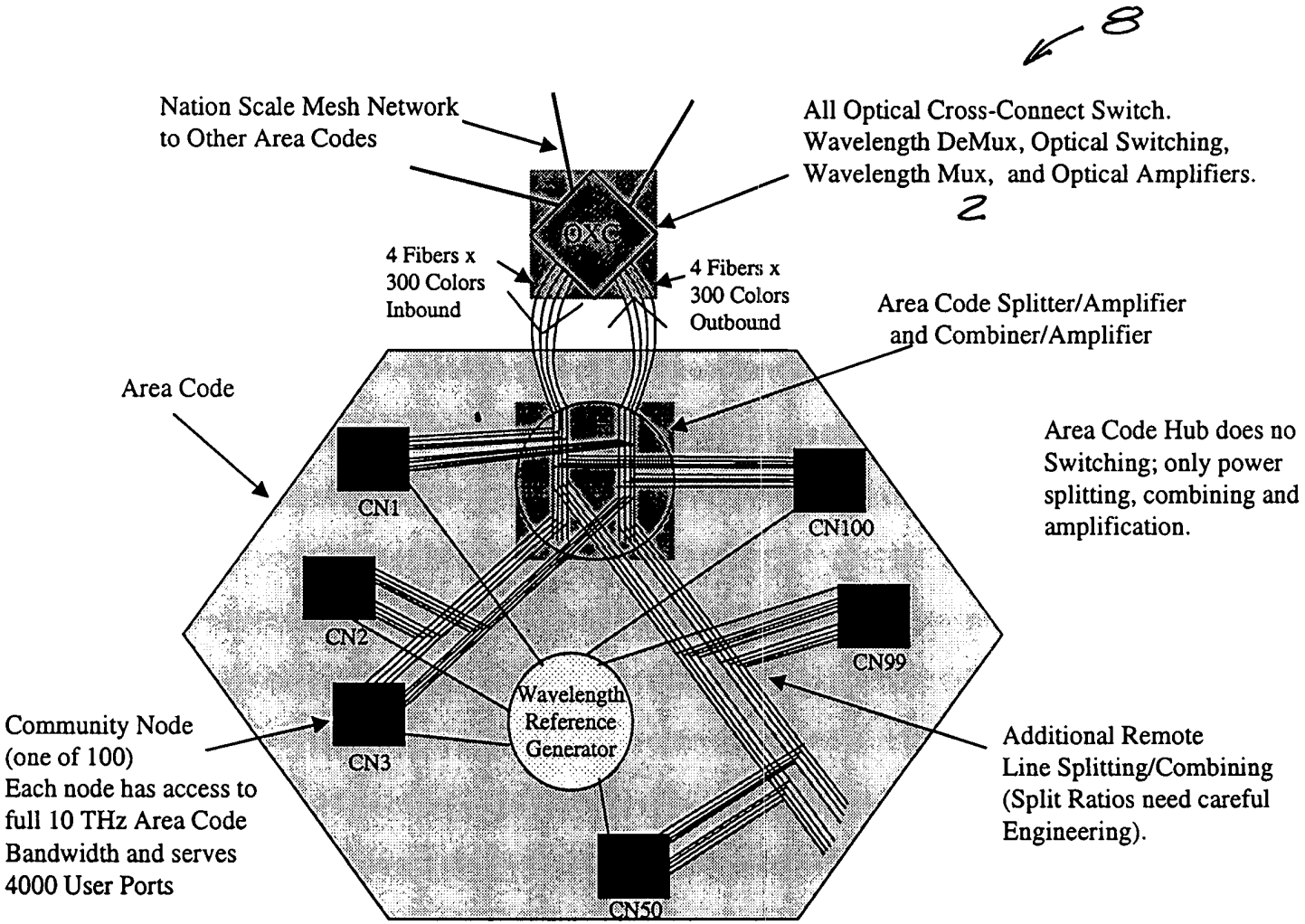

8
Nation Scale Mesh Network
to Other Area Codes
All Optical Cross-Connect Switch.
Wavelength DeMux, Optical Switching,
Wavelength Mux, and Optical Amplifiers.
2
OXC
4 Fibers x
300 Colors
Inbound
4 Fibers x
300 Colors
Outbound
Area Code Splitter/Amplifier
and Combiner/Amplifier
Area Code
Area Code Hub does no
Switching; only power
splitting, combining and
amplification.
CN1
CN100
CN2
CN99
Wavelength
Reference
Generator
Community Node
(one of 100)
Each node has access to
full 10 THz Area Code
Bandwidth and serves
4000 User Ports
CN3
Additional Remote
Line Splitting/Combining
(Split Ratios need careful
Engineering).
CN50

FIG. 2

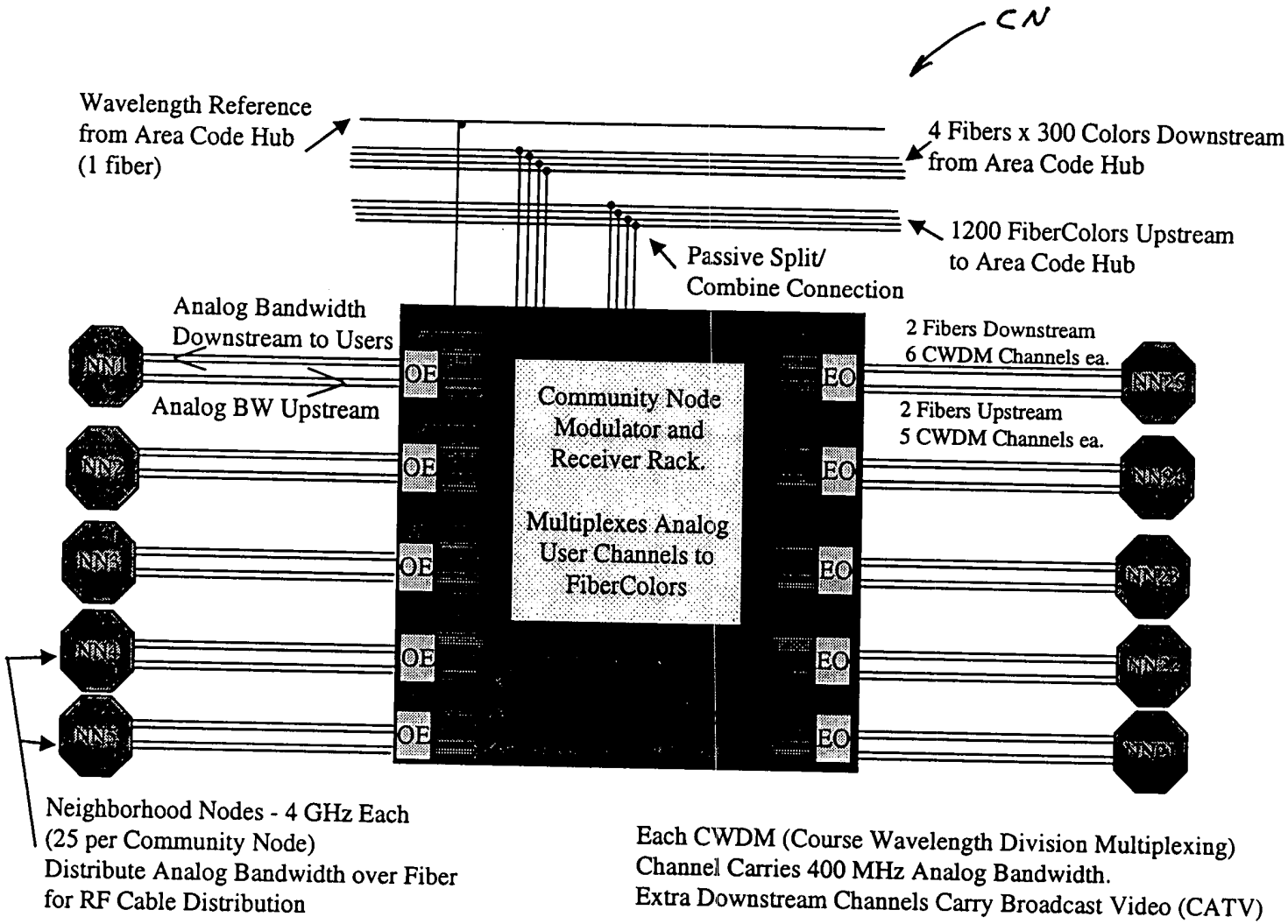

CN
Wavelength Reference
from Area Code Hub
(1 fiber)
4 Fibers x 300 Colors Downstream
from Area Code Hub
1200 FiberColors Upstream
to Area Code Hub
Passive Split/
Combine Connection
Analog Bandwidth
Downstream to Users
Analog BW Upstream
2 Fibers Downstream
6 CWDM Channels ea.
2 Fibers Upstream
5 CWDM Channels ea.
Community Node
Modulator and
Receiver Rack.
Multiplexes Analog
User Channels to
FiberColors
OE
EO
NN1
NN2
NN3
NN4
NN5
NN25
NN24
NN23
NN22
NN21
Neighborhood Nodes - 4 GHz Each
(25 per Community Node)
Distribute Analog Bandwidth over Fiber
for RF Cable Distribution
Each CWDM (Course Wavelength Division Multiplexing)
Channel Carries 400 MHz Analog Bandwidth.
Extra Downstream Channels Carry Broadcast Video (CATV)

FIG. 3

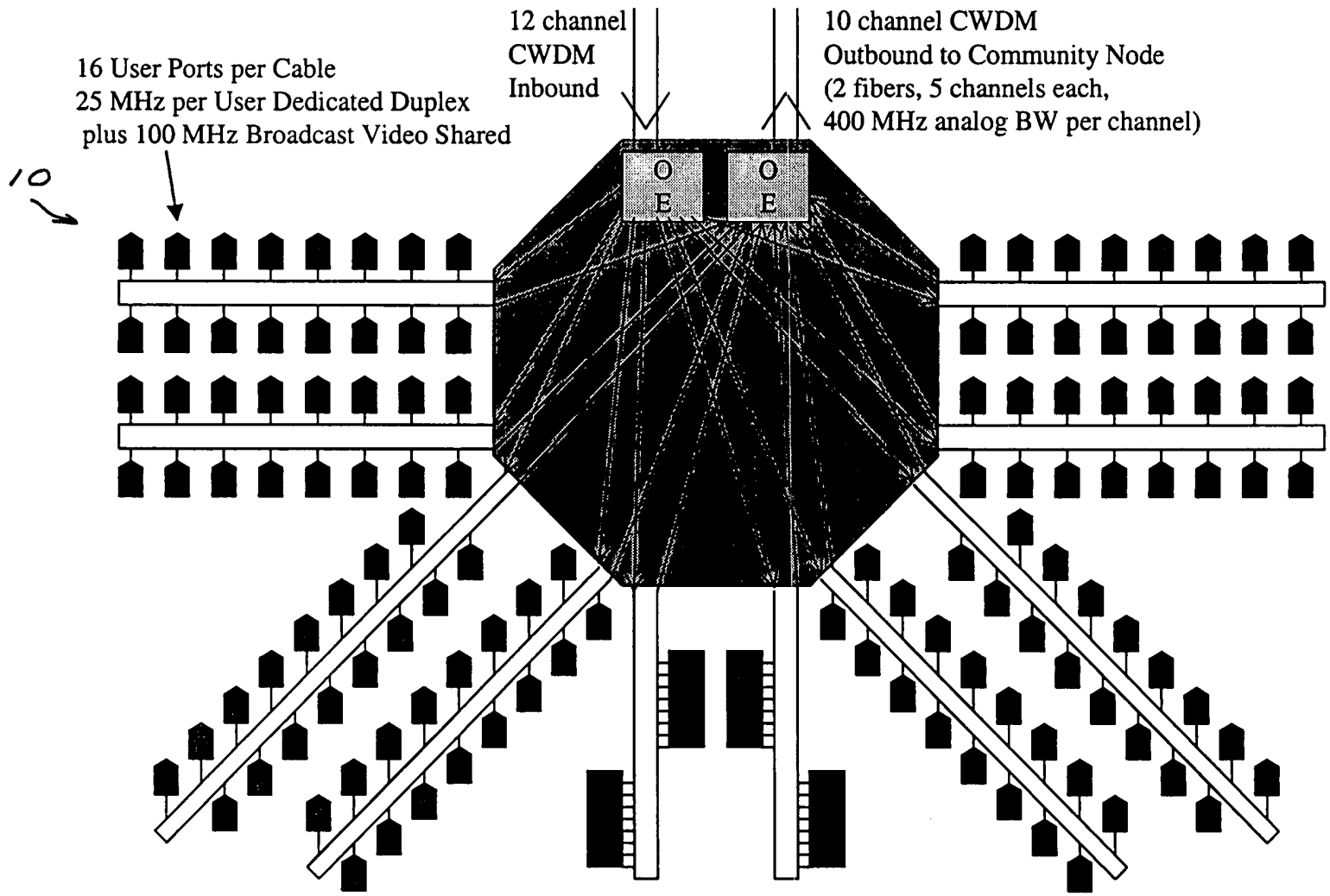

16 User Ports per Cable
25 MHz per User Dedicated Duplex
plus 100 MHz Broadcast Video Shared
10
12 channel
CWDM
Inbound
10 channel CWDM
Outbound to Community Node
(2 fibers, 5 channels each,
400 MHz analog BW per channel)
O
E
O
E

FIG. 4

-Accurate Laser Wavelength Comb Generated at Area Code Node
-Or Regenerated from Central Network Reference Source
-Standard WDM 50 GHz spacings used, to allow straightforward wavelength demux and mux in network
-More accurate wavelength control (frequency to 500 MHz) used within area code.

-Source wavelengths either from multi-frequency fiber lasers, or from modulated DWDM lasers

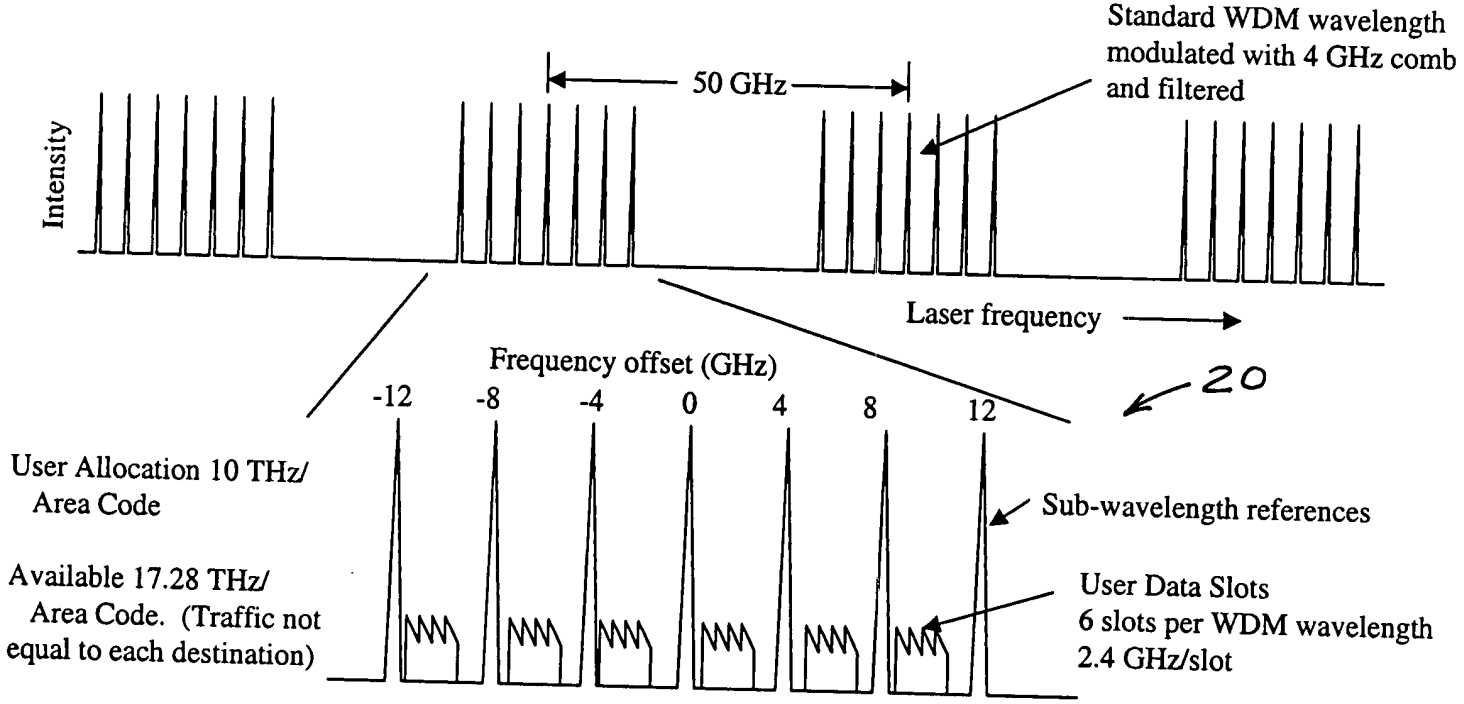


FIG. 5

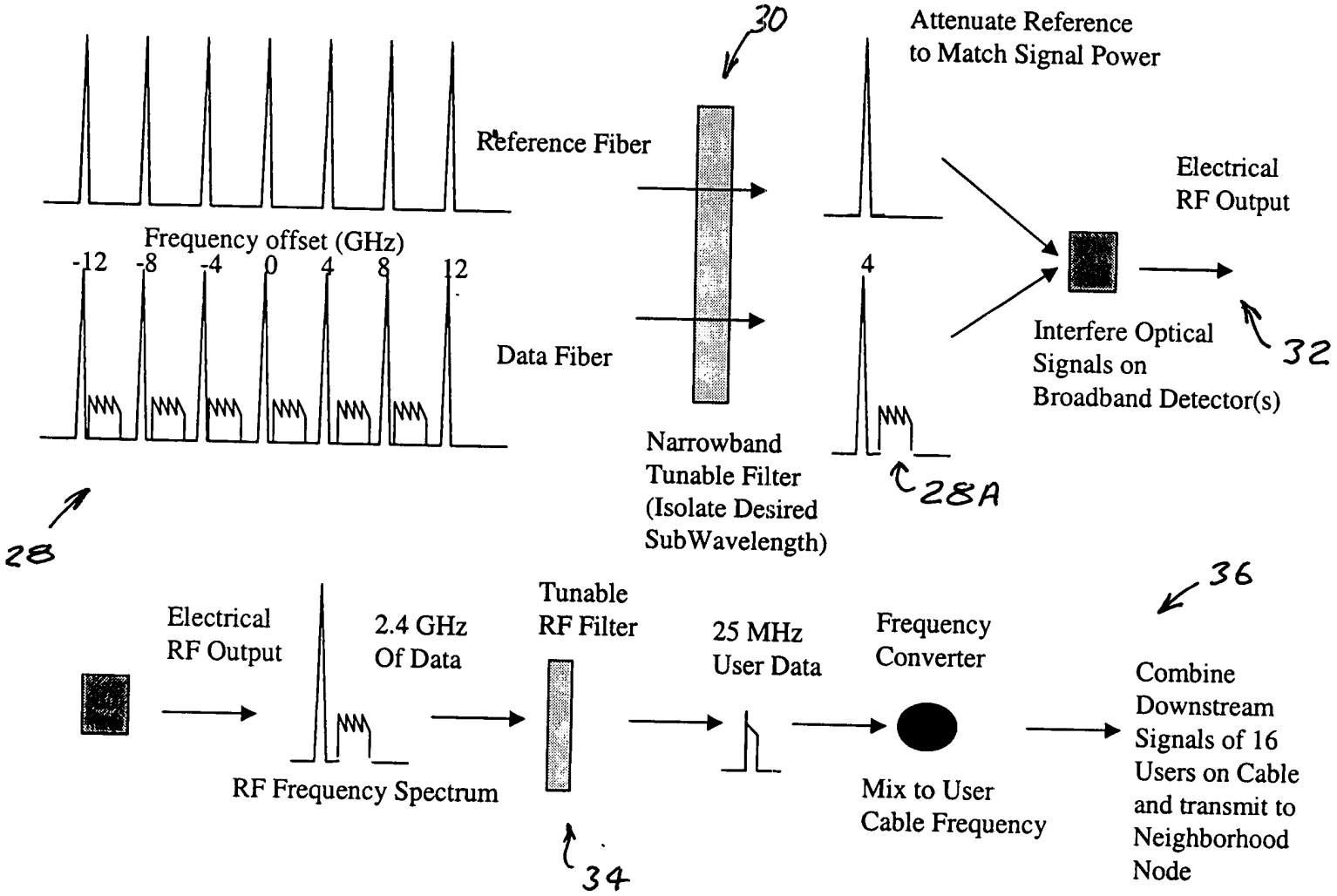

30
Attenuate Reference
to Match Signal Power
Reference Fiber
Electrical
RF Output
Frequency offset (GHz)
-12 -8 -4 0 4 8 12
4
Data Fiber
Interfere Optical
Signals on
Broadband Detector(s)
32
Narrowband
Tunable Filter
(Isolate Desired
SubWavelength)
28A
28
36
Electrical
RF Output
2.4 GHz
Of Data
Tunable
RF Filter
25 MHz
User Data
Frequency
Converter
Combine
Downstream
Signals of 16
Users on Cable
and transmit to
Neighborhood
Node
RF Frequency Spectrum
34
Mix to User
Cable Frequency

FIG. 6

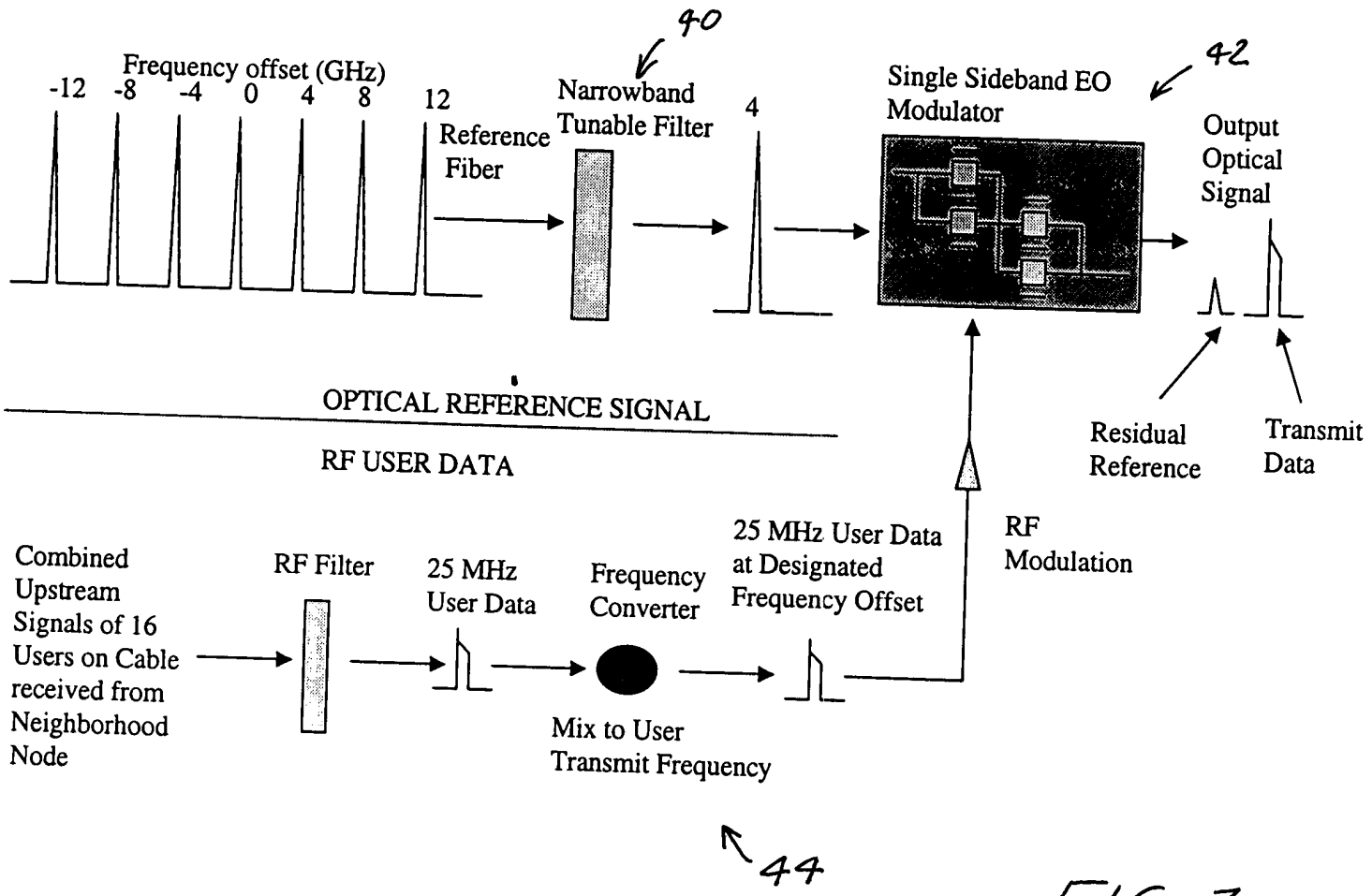

40
Frequency offset (GHz)
-12
-8
-4
0
4
8
12
Reference Fiber
Narrowband Tunable Filter
4
Single Sideband EO Modulator
42
Output Optical Signal
OPTICAL REFERENCE SIGNAL
RF USER DATA
Residual Reference
Transmit Data
Combined Upstream Signals of 16 Users on Cable received from Neighborhood Node
RF Filter
25 MHz User Data
Frequency Converter
25 MHz User Data at Designated Frequency Offset
RF Modulation
Mix to User Transmit Frequency
44

FIG. 7

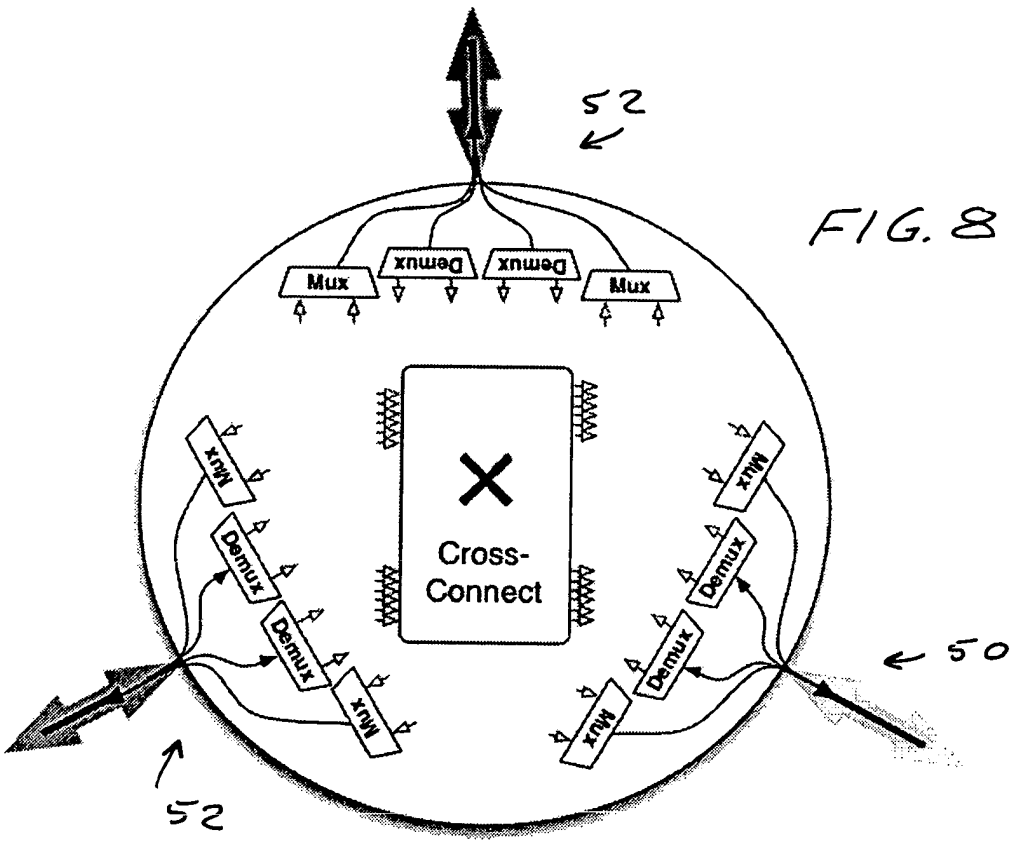
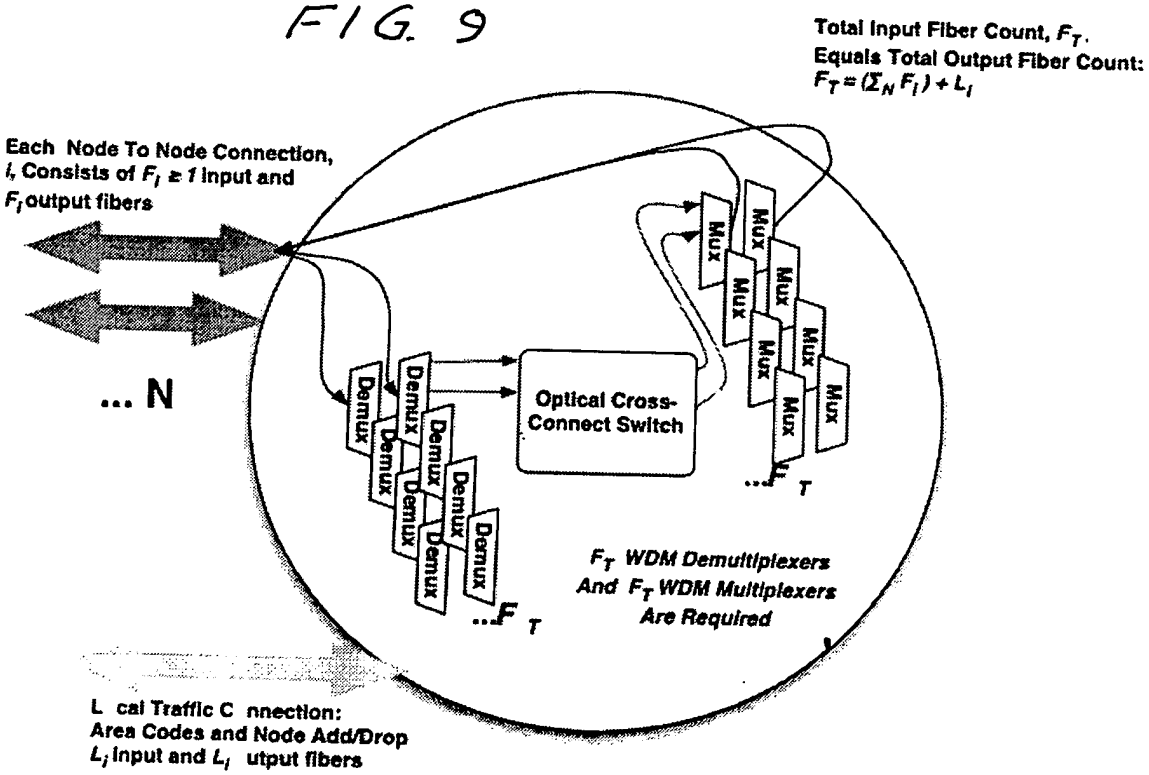

52
Mux
Demux
Demux
Mux
Cross-
Connect
Mux
Demux
Demux
Mux
Demux
Demux
Mux
Mux
50
52

FIG. 8

FIG. 9


Total Input Fiber Count, F_T.
Equals Total Output Fiber Count:
$F_T = (\Sigma_N F_i) + L_i$
Each Node To Node Connection,
i, Consists of $F_i \geq 1$ Input and
F_i output fibers
... N
Optical Cross-
Connect Switch
Demux
Mux
...F_T
...F_T
F_T WDM Demultiplexers
And F_T WDM Multiplexers
Are Required
Local Traffic Connection:
Area Codes and Node Add/Drop
L_i Input and L_i Output fibers

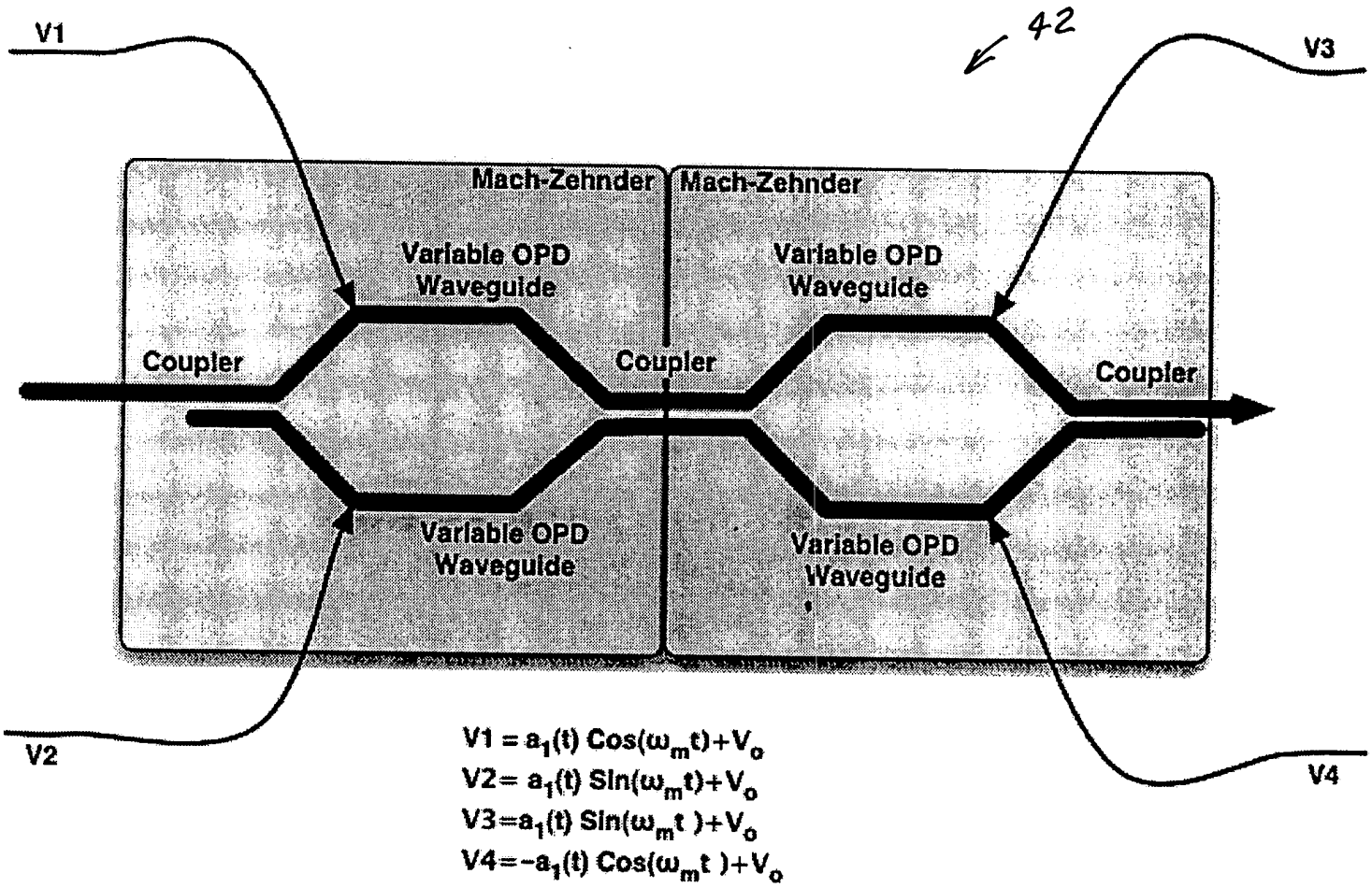

42
V1
V3
Mach-Zehnder
Mach-Zehnder
Variable OPD Waveguide
Variable OPD Waveguide
Coupler
Coupler
Coupler
Variable OPD Waveguide
Variable OPD Waveguide
V2
V4
V1 = a1(t) Cos(ωmt)+Vo
V2= a1(t) Sin(ωmt)+Vo
V3=a1(t) Sin(ωmt)+Vo
V4=-a1(t) Cos(ωmt)+Vo

FIG. 10

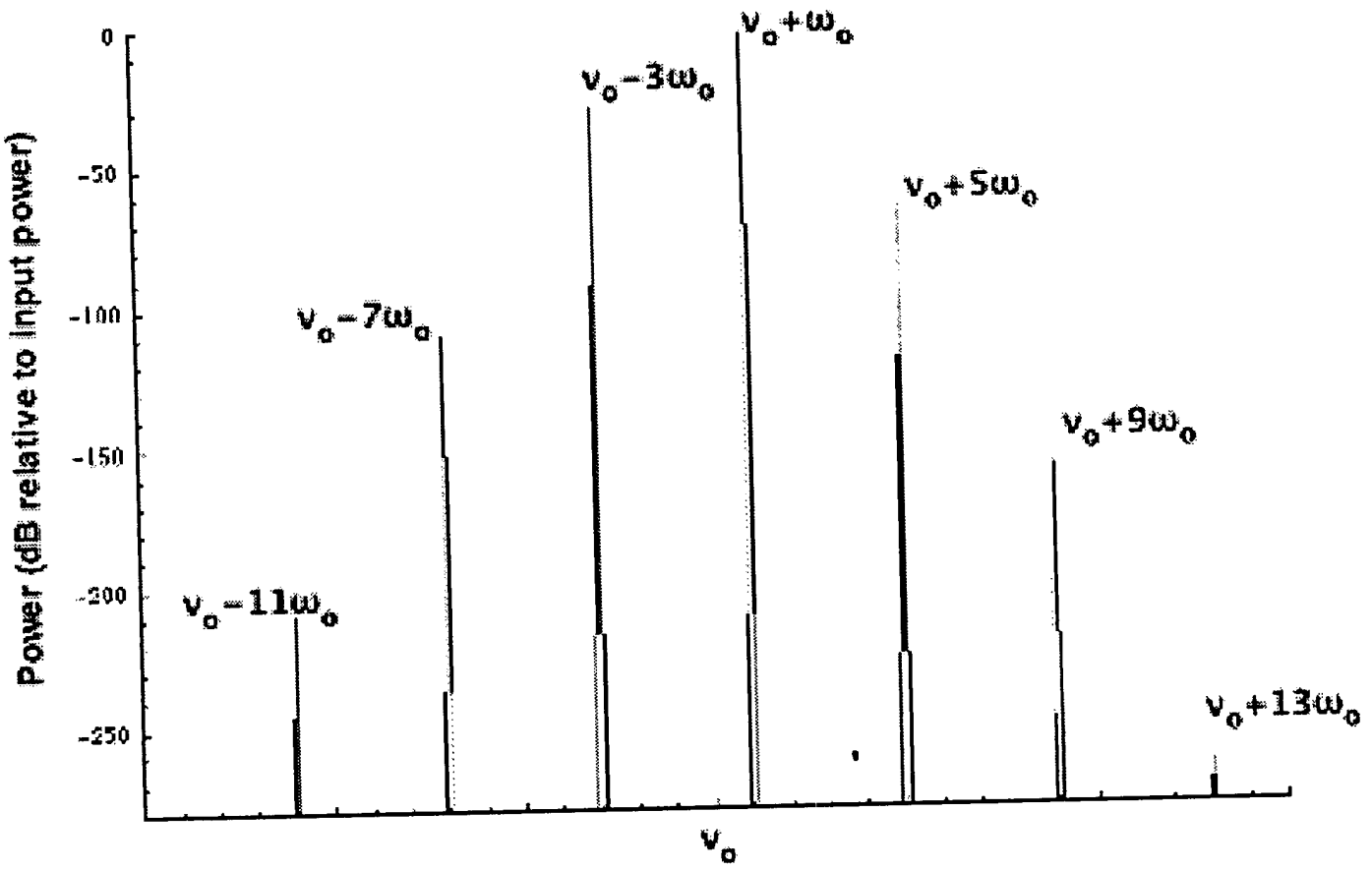

Power (dB relative to input power)
0
-50
-100
-150
-200
-250
$\nu_o - 11\omega_o$
$\nu_o - 7\omega_o$
$\nu_o - 3\omega_o$
$\nu_o + \omega_o$
$\nu_o + 5\omega_o$
$\nu_o + 9\omega_o$
$\nu_o + 13\omega_o$
ν_o

FIG. 11

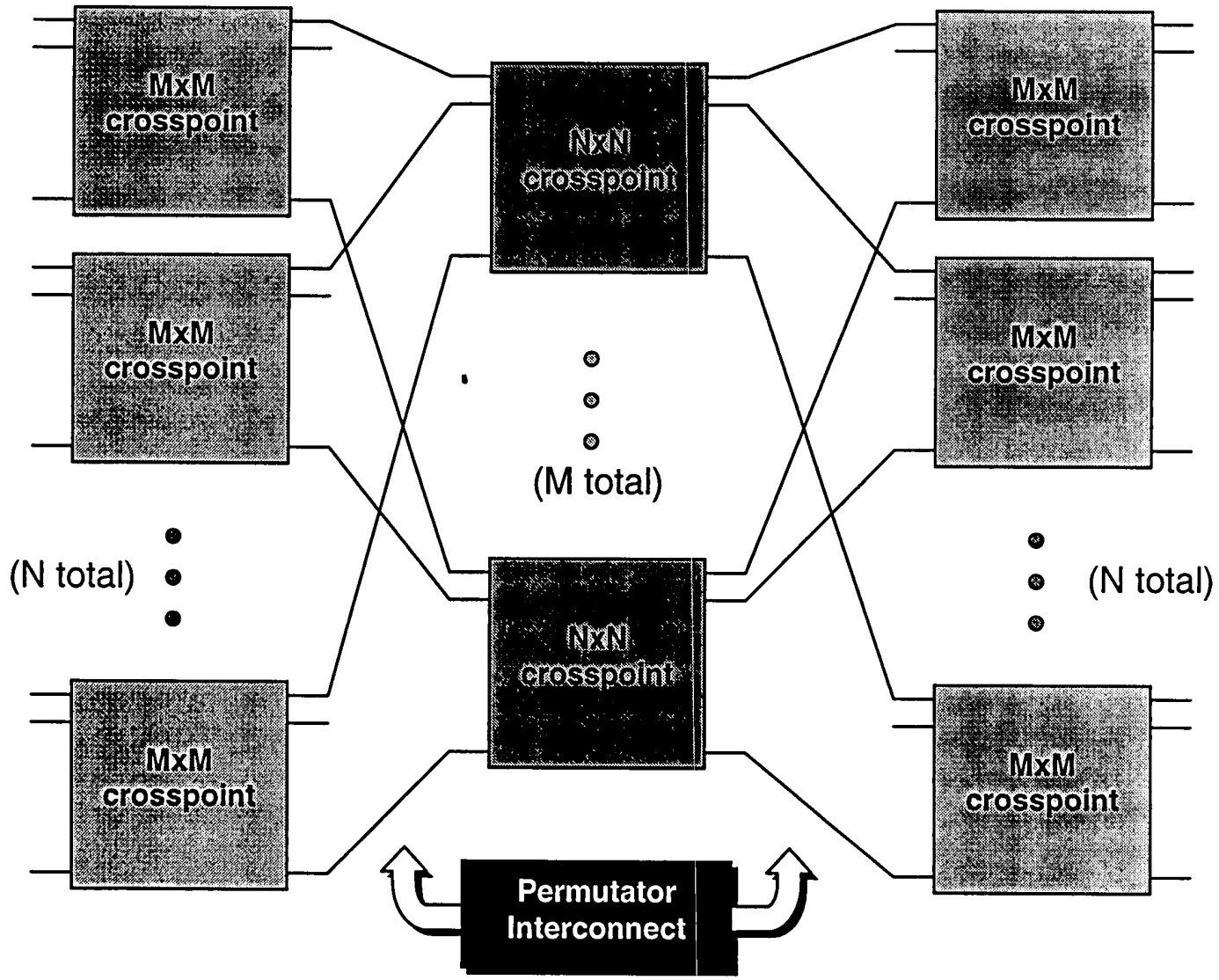

MxM crosspoint
MxM crosspoint
MxM crosspoint
(N total)
NxN crosspoint
(M total)
NxN crosspoint
Permutator Interconnect
MxM crosspoint
MxM crosspoint
MxM crosspoint
(N total)

FIG. 12

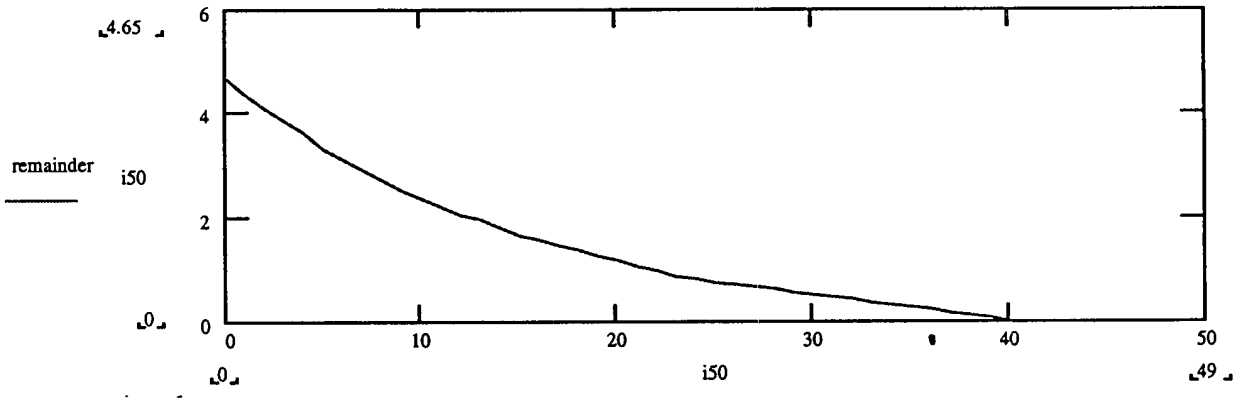


FIG. 14

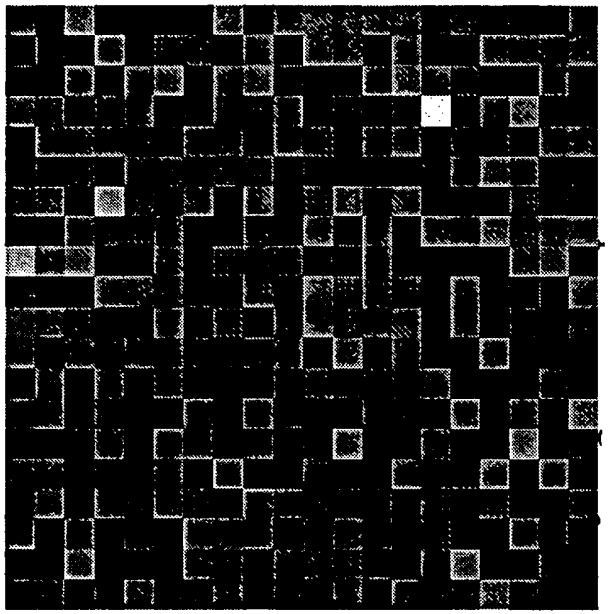


FIG. 13

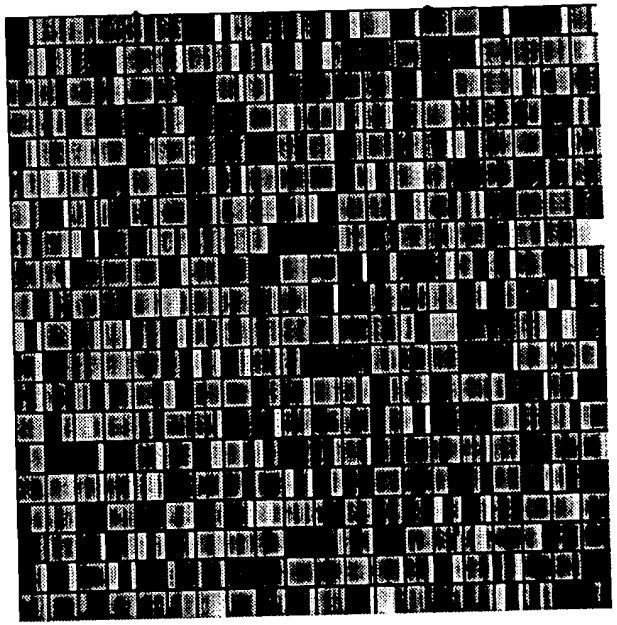


FIG. 15

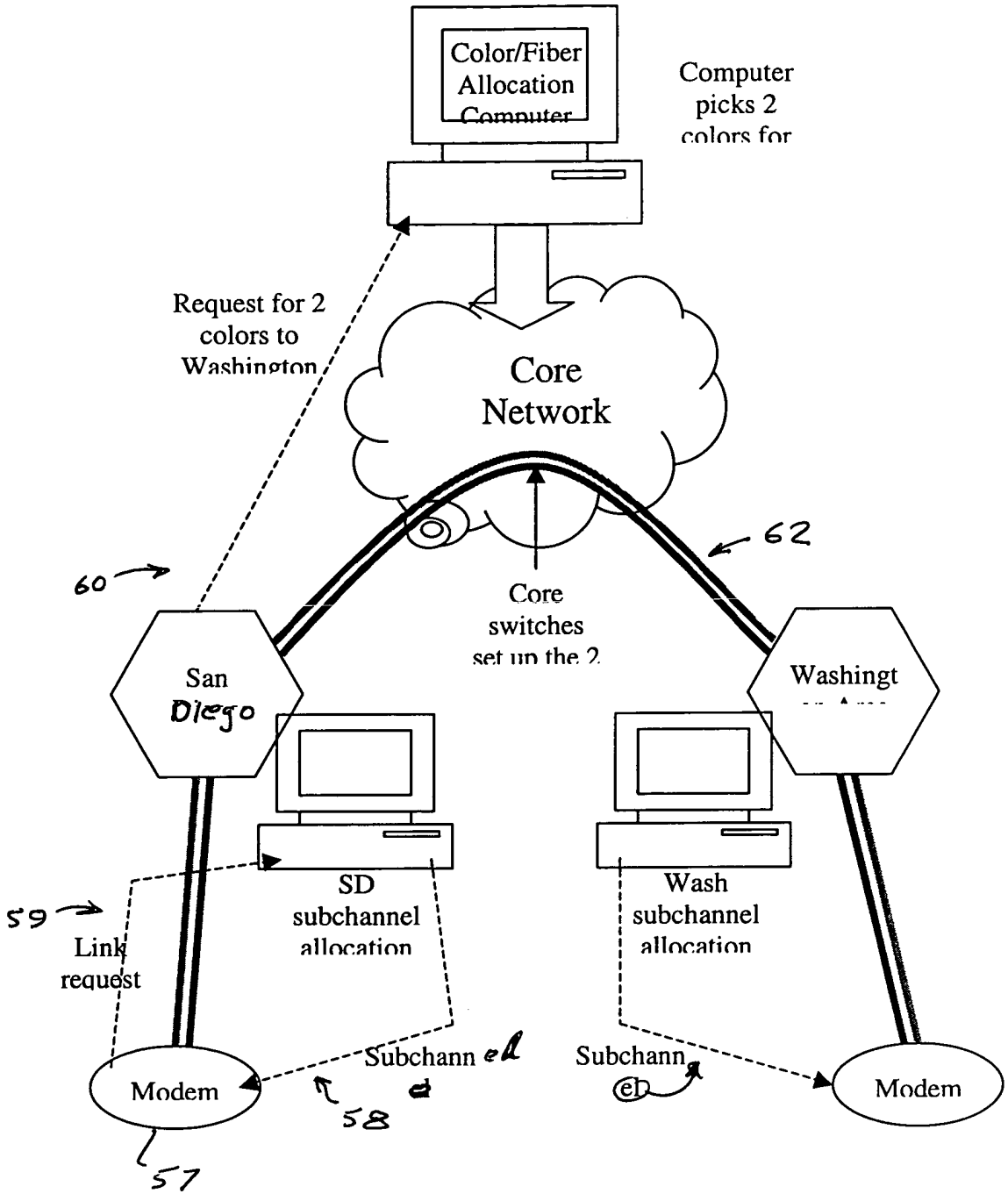

Color/Fiber Allocation Computer
Computer picks 2 colors for
Request for 2 colors to Washington
Core Network
62
60
Core switches set up the 2
San Diego
Washingt
SD subchannel allocation
Wash subchannel allocation
59
Link request
Subchann el
Subchann el
Modem
Modem
58
57

FIG. 16